

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(54) Title:</b> (CO)POLYMER MODIFICATION EMPLOYING UNSATURATED t-ALKYL PEROXYALKENYL CARBO-NATES  <b>(57) Abstract</b>  (Co)polymers are modified by contacting them with one or more tertiary alkyl peroxy alkenyl carbonates and decomposing the peroxide. By this process the physical properties of the (co)polymers, such as adhesion to polar substrates and lap shear strength, can be enhanced. According to a preferred embodiment, the modification reaction is carried out in the presence of a coagent whereby the advantageous polymer properties, such as adhesion to polar materials, are further enhanced. Also disclosed are shaped objects manufactured using the modified (co)polymers prepared by the process of the present invention.		

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## (Co)polymer Modification Employing Unsaturated t-Alkyl Peroxyalkenyl Carbonates

The invention relates to compounds useful in modifying (co)polymers, a process for modifying (co)polymers with these compounds, and to shaped objects comprising the modified (co)polymers.

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It is generally known that the introduction of epoxide or other functional groups into the appropriate (co)polymers may lead to improved physical and chemical properties of the (co)polymers. According to Rubber World 191(6), pp. 15-20 (1985) and Rubber Developments, Vol. 38, No. 2, pp. 48-50 (1985), for instance, the introduction of epoxide groups into natural rubber leads to advantages such as an increased glass transition temperature, increased oil resistance, reduced gas permeability, improved resilience, increased tensile strength and improved adhesion to other materials, such as silica fillers, glass fibers and other polymers such as PVC. Further, the polymers thus modified can be subjected to chemical reactions that are typical of epoxy groups. As examples thereof may be mentioned: i) cross-linking the polymer with polyfunctional compounds containing active hydrogen atoms, such as polyamines and dibasic acids, which is described in Chemical Reactions of Polymers, E.M. Fettes (ed.), Interscience Publications, New York (1964), chapter II, part E, pp. 152 et. seq., ii) covalently bonding antioxidants having amino groups to the polymer, which is described in Journal of Polymer Science, Polymer Letters Edition, Vol. 22, pp. 327-334 (1984) and iii) reacting the polymer with fluorine-containing compounds, such as trifluoroacetic acid, resulting in a polymer with improved lubricity and ozone resistance, which is described in WO 85/03477.

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Generally, epoxide groups are introduced into (co)polymers by so-called epoxidation reactions, in which an unsaturated (co)polymer in the form of a latex or dissolved in an organic solvent, is brought into contact with an epoxidizing reagent suitable for reacting with unsaturation present in the (co)polymer. An example of such compounds are the lower aliphatic carboxylic acids. This method, however,

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suffers from several disadvantages. First, the requirement that the (co)polymer be unsaturated significantly limits the number of (co)polymers that can be epoxidized by this method. For example, saturated polymers such as polypropylene cannot be functionalized using this method.

Secondly, the use of solvents in the epoxidation reaction necessitates a subsequent purification step for residual solvent removal. Such a purification step is disadvantageous from a polymer processing standpoint since it adds an additional, costly processing step. Further, disposal of solvents is becoming an increasing concern because of the environmental hazards these solvents create.

Thirdly, this type of epoxidation reaction is always accompanied by undesirable side reactions, such as the formation of hydroxyl groups, acyloxy groups, ether groups, keto groups and aldehyde groups. These side reactions cause numerous problems when such epoxidation reactions are employed.

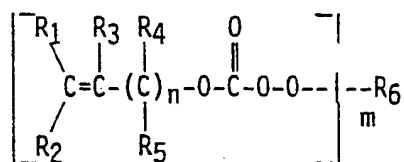
It is also known to prepare epoxide group-containing (co)polymers by copolymerization and graft copolymerization reactions with monomers containing a glycidyl group (cf. Journal of Polymer Science, Vol. 61, pp. 185-194 (1962), Makromol. Chem., Rapid Commun. 7, pp. 143-148 (1986) and Die Angewandte Makromolekulare Chemie 48, pp. 135-143 (1975)). The inevitable accompanying formation of undesirable side products, such as the formation of homopolymers of the glycidyl group-containing monomer, is a significant drawback to the practice of this method. Moreover, this method only permits preparation of a limited group of modified (co)polymers.

Bull. Soc. Chim. France No. 2, 198-202 (1985) discloses t-butyl allyl peroxide and its use for epoxypropanating organic solvents with labile hydrogen atoms. As solvents are mentioned cyclohexane, tetrahydrofuran, propionic acid, propionic anhydride, methyl propionate, acetonitrile and chloroform.

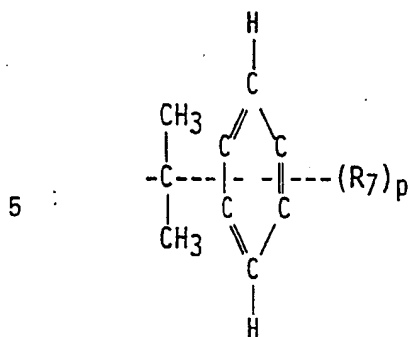
European Patent Application 0 273 990 (Akzo) discloses the use of certain unsaturated organic peroxides in the preparation of epoxide groups-containing (co)polymers. These compounds have been shown to be effective in introducing epoxide groups onto (co)polymers. However, this patent application does not disclose the compounds of the present invention. More particularly, the peroxides of the present invention are significantly different than those of European Patent Application 0 273 990 since they contain a carbonate group between the peroxy group and the unsaturation. This is important since the present compounds are incapable of rearranging in the same manner as shown in the European Patent Application 0 273 990 and since the unsaturated free radicals generated by the present peroxycarbonates will contain a carbonate group therein.

The present invention has for its object the elimination of the drawbacks of the prior art. In addition, the present invention is useful in introducing cyclic carbonate or ketone functionalities onto polymers instead of or in addition to epoxy functionalities. As a result, the modified polymers made by the present invention are useful in a wider variety of applications.

For these purposes, the present invention provides a process for modification of (co)polymers employing particular organic peroxides of the following formula:



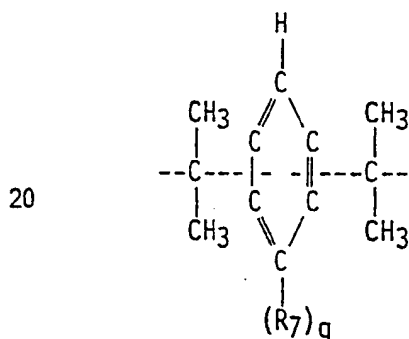
wherein  $R_1$ ,  $R_2$ ,  $R_4$ , and  $R_5$  may be the same or different and represent H or  $C_{1-4}$  alkyl groups;  $n = 0$  or  $1$ ;  $m = 1, 2$ , or  $3$ ;  $R_3 = H$ ,  $C_{1-4}$  alkyl or an electron withdrawing group; and when  $m=1$ ,  $R_6 =$  a tertiary alkyl group optionally substituted with a hydroxyl group and containing 4-18 carbon atoms, p-menth-8-yl or a group of the general formula:



10 wherein  $p = 0, 1$  or  $2$  and  $R_7$  is an isopropenyl group, a 2-hydroxyisopropyl group, or an isopropyl group;

when  $m = 2$ ,  $R_6$  = an alkylene group having 8-12 carbon atoms and a tertiary structure at both ends thereof, an alkynylene group having 8-12 carbon atoms and a tertiary structure at both ends thereof, or a group of the general formula:

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25 wherein  $q = 0$  or  $1$  and  $R_7$  has the above-indicated meaning; and when  $m = 3$ ,  $R_6$  = 1,2,4-triisopropylbenzene- $\alpha, \alpha', \alpha''$ -triyl or 1,3,5-triisopropylbenzene- $\alpha, \alpha', \alpha''$ -triyl.

The alkyl, alkenyl and alkylene groups may be linear or branched, unless otherwise indicated.

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The present invention also relates to articles of manufacture comprising one or more (co)polymers modified by the process of the present invention. More particularly, the (co)polymers modified by the process of the present are excellently suited for the manufacture of shaped objects.

Some of the compounds of the formula (I) are known in the prior art. For example, for formula (I) when  $n=0$ , species of these compounds are disclosed in Japanese Patent Application J5 9036-105-A and "A Convenient One-Step Synthesis of 1,4-Diketones," Synthetic Communications, 13(5), 361-366 (1983). These publications also disclose methods of preparing peroxycarbonates useful in the process of the present invention. To the extent that these preparation methods are disclosed, the disclosures of these publications are hereby incorporated by reference. However, these publications disclose the process of the present invention.

Compounds of the formula (I) when  $n=1$  are disclosed in German patent application numbers DT 27 286 008 and DE 3420-048-A, British patent application GB 2081-282 and Japanese patent application numbers J6 1002-711-A, J6 1002-753-A, J5 4076-691, J5 5009-636, J6 1157-551-A and J5 4047-790. All of these published patent applications relate to the use of these unsaturated peroxycarbonates to form copolymers with various unconjugated or other monomers. These publications also disclose methods of preparing peroxycarbonates useful in the process of the present invention. To the extent that these preparation methods are disclosed, the disclosures of these publications are hereby incorporated by reference. None of these publications discloses the process of the present invention.

Finally, the use of unsaturated peroxycarbonates as polymerization initiators and as curing catalysts is disclosed in Canadian patent number 1,025,467 and U.S. patent number 4,136,105. Again, the process of the present invention is not disclosed in these publications.

Generally, the synthetic routes for making the tertiary alkyl peroxy alkenyl carbonates used in the process of the present invention are known in the art. The preferred mode of synthesizing these compounds is to react the appropriate tertiary alkyl hydroperoxide with an unsaturated chloroformate, separate the organic layer and subsequently

wash this material to provide the desired product in relatively pure form.

Suitable tertiary alkyl hydroperoxides use in this synthesis process include t-butyl hydroperoxide, t-pentyl hydroperoxide, t-octyl-2-hydroperoxide, and t-hexyl hydroperoxide, among others. Suitable unsaturated chloroformates include allyl chloroformate, 2-propenyl chloroformate, isopropenyl chloroformate, 2-methyl-2-propenyl chloroformate, 3-methyl-2-butenyl chloroformate, 3-butenyl-2-chloroformate, 2-propenyl-2-chloroformate, and 2-butenyl chloroformate among others.

Typical examples of tertiary alkyl peroxy alkenylcarbonates according to the invention include t-butylperoxy allylcarbonate, t-pentylperoxy allylcarbonate, t-butylperoxy isopropenylcarbonate, t-pentylperoxy allylcarbonate, 2,5-bis(peroxyallylcarbonate) 2,5-dimethyl hexane, t-nonylperoxy 2-methyl-2-pentene carbonate, t-butylperoxy-2-propenyl carbonate, t-butylperoxy-2-methyl-2-propene carbonate, t-butylperoxy-2-butene carbonate, t-pentylperoxy-2-propene carbonate, t-pentylperoxy-2-butene carbonate, t-hexyl peroxy-1,1-dimethyl-2-propene carbonate, t-butylperoxy-4-methyl-2-butene carbonate di-t-butyl peroxy-2-propene dicarbonate, and t-octyl peroxy 2-propene carbonate.

The peroxides can be prepared, transported, stored and applied as such or in the form of powders, granules, solutions, aqueous suspensions, emulsions or pastes. Other forms may also be useful in specific circumstances.

Which of these forms is to be preferred partly depends on the ease of feeding the peroxide into closed systems. Also, considerations of safety may play a role to the extent that desensitizing agents may have to be incorporated in certain compositions to ensure their safety. As examples of suitable desensitizing agents may be mentioned solid carrier materials such as silica, chalk and clay, inert plasticizers or solvents such as mono- or dichlorobenzene, and water.



The present t-alkylperoxy alkenylcarbonates are exceptionally well suited for use in the preparation of epoxide, cyclic carbonate and/or ketone groups-containing (co)polymers, in which process a non-modified (co)polymer is brought into contact with the t-alkylperoxy alkenylcarbonate in order to cause modification of the (co)polymer.

The peroxy alkenylcarbonate may be brought into contact with the (co)polymer in various ways, depending upon the particular object of the modification process. For example, if surface modification of a three dimensional polymeric object is desired, the t-alkylperoxy alkenylcarbonate may simply be applied to the surface of the material to be modified. Alternatively, it is often desirable to distribute functional groups homogeneously throughout the (co)polymeric matrix. In this instance, the t-alkylperoxy alkenylcarbonate may be mixed with the material to be modified, which material may be in the molten state, in the form of a solution, or, in the case of an elastomer, in a plastic state. To accomplish homogeneous mixing of the material to be modified and the t-alkylperoxy alkenylcarbonate, most conventional mixing apparatus may be used. Typical mixing apparatus includes kneaders, internal mixers and (mixing) extruding equipment. Should mixing be a problem for a particular material because of its high melting point, for example, the (co)polymer can first be provided with functional groups on its surface while in the solid state and subsequently melted and mixed to distribute the functional groups throughout the material.

Alternatively, the (co)polymer may be first dissolved and the reaction with the present t-alkylperoxy alkenylcarbonates can then be carried out in solution.

An important practical aspect of the present invention is that the moment the t-alkylperoxy alkenylcarbonate and the (co)polymer are brought into contact with each other and also the moment that the t-alkylperoxy alkenylcarbonate is to react with the (co)polymer can be chosen independently of the other usual polymer processing steps,

including the introduction of additives, shaping, etc. For instance, the modification may be done before other additives are introduced into the polymer or after the introduction of other additives. More importantly, it is possible to accomplish the present polymer  
5 modification during a polymer shaping step such as extrusion, compression moulding, blow moulding or injection moulding. The sole restriction applies to polymers which are to be cross-linked. In that case the t-alkylperoxy alkenylcarbonate should be contacted with the (co)polymer prior to cross-linking.

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Examples of suitable (co)polymers which according to the present invention can be modified by means of epoxide or other types of functional groups such as carbonate groups, for example, are saturated (co)polymers such as polyethylene, e.g. LLDPE, MDPE, LDPE, and HDPE,  
15 polypropylene, both isotactic and atactic, polyphenylene ether, ethylene/vinyl acetate copolymer, ethylene/ethylacrylate copolymer, ethylene/methylmethacrylate copolymer, ethylene/methacrylate copolymer, chlorinated polyethylene, fluorrubber, silicone rubber, polyurethane, polysulphide, polyacrylate rubber, ethylene/propylene  
20 copolymer, polyphenylene oxides, nylon, polyesters such as polyethylene terephthalate and polybutylene terephthalate, polycarbonates, copolyetheresters, poly(butene-1), poly(butene-2), poly(isobutene), poly(methylpentene), polyvinyl chloride/acrylonitrile graft copolymer, and combinations thereof. Unsaturated (co)polymers  
25 may also be modified by the unsaturated tertiary alkyl peroxy alkenyl carbonate of the present invention. Suitable unsaturated (co)polymers include polybutadiene, polyisoprene, poly(cyclopentadiene), poly(methylcyclopentadiene), partly dehydrochloridated polyvinyl chloride, butadiene/styrene copolymer, acrylonitrile/butadiene/styrene  
30 terpolymer, ethylene/propylene/dienemonomer terpolymer, isoprene/styrene copolymer, isoprene/isobutylene copolymer, isoprene/styrene/acrylonitrile terpolymer, polychloroprene, butadiene/acrylonitrile copolymer, natural rubber, and combinations thereof. Also, combinations of saturated and unsaturated polymers can

be modified in accordance with the present invention. In general, any (co)polymer comprising abstractable hydrogen atoms can be modified by the present process.

5 It has been found that when certain (co)polymers are contacted with the present peroxy alkenylcarbonates, some degradation of the polymer chains may occur. This degradation may affect the mechanical properties of the modified (co)polymer. Those polymers which are prone to formation of tertiary carbon radicals under the conditions of free  
10 radical reactions tend to undergo degradation. For instance, polymers which tend to degrade include polyisobutylene, poly( $\alpha$ -methyl)-styrene, polymethacrylates, polymethacrylamide, polyvinylidene chloride, polypropylene and particularly isotactic polypropylene, and polyvinyl alcohol. According to a preferred embodiment of the present  
15 invention, the modification process is conducted in the presence of a coagent in order to reduce or prevent the negative effects of polymer degradation or enhance the degree of modification of the (co)polymer.

A coagent is generally understood to be a polyfunctional reactive  
20 additive such as a polyunsaturated compound which will react rapidly with polymer radicals, will overcome steric hindrance effects and will minimize undesirable side reactions. Further information about coagents (which are sometimes called coactivators) is set forth in Rubber Chemistry and Technology, Vol. 61, pp. 238-254 and W. Hofmann,  
25 Progress in Rubber and Plastics Technology, Vol. 1, No. 2, March 1985, pp. 18-50, the disclosures of which are hereby incorporated by reference. In relation to the present invention the term "coagent" has the same meaning as given in these publications.

30 A wide variety of useful coagents are commercially available including di- and triallyl compounds, di- and tri(meth)acrylate compounds, bismaleimide compounds, divinyl benzene, vinyl toluene, vinyl pyridine, parachinone dioxime, 1,2-cis-polybutadiene and their derivatives. Furthermore, other useful coagents also include

oligomers of 1,3-diisopropenyl benzene, 1,4-diisopropenyl benzene, and 1,3,5-triisopropenyl benzene.

5 The incorporation of an effective amount of one or more of these coagents into the (co)polymer prior to or during the reaction with the present peroxy alkenylcarbonates will tend to reduce or prevent the degradation of the modified materials and thereby maintain the mechanical properties at the same level or better. Surprisingly, in some cases the coagent may result in improved mechanical properties  
10 such as an enhanced adhesion strength in modified (co)polymers of a polar nature. This enhancement may be attributable to a greater degree of functional group introduction into the (co)polymer resulting from the presence of a coagent.

15 It may be preferable to modify polymers less liable to undergo degradation in the presence of coagents due to the greater amount of functional groups which can be introduced into the modified (co)polymer with the same quantity of peroxy alkenylcarbonate, in this manner. Such polymers, which are typically those that are  
20 cross-linked when contacted with peroxides, include polyethylene, atactic polypropylene, polystyrene, polyacrylates, polyacrylamides, polyvinylchloride, polyamides, aliphatic polyesters, polyvinylpyrrolidone, unsaturated rubbers, polysiloxanes, ethylene/propylene rubbers, ethylene/propylene/diene rubbers and their  
25 copolymers.

As a result of the present invention, the extremely useful physical and chemical properties resulting from the presence of epoxide, cyclic carbonate and/or ketone groups on the (co)polymers, can now be  
30 obtained with an extremely large group of (co)polymers. The introduction of carbonate functionalities onto polymers is particularly useful for producing polyhydroxy or other types of polyurethanes without employing isocyanates such as is described in U.S. patent no. 3,084,140 and "Polyurethane Elastomers Obtained

Without the Use of Diisocyanates," Rappoport, L.Ya. et al., International Polymer Science and Technology, 8, No. 1, 1981, the disclosures of which are hereby incorporated by reference. In addition, further uses of cyclic carbonate-containing polymers are  
5 detailed in U.S. patent 2,935,494, the disclosure of which is also hereby incorporated by reference.

The most preferred (co)polymers for modification by the compounds of the present invention are polyethylene, polypropylene,  
10 ethylene/propylene copolymer, ethylene/vinyl acetate copolymer, and ethylene/propylene/dienemonomer terpolymer.

The peroxy alkenylcarbonate of the present invention is generally used in an amount of 0.01 to 15% by weight, preferably 0.1 to 10% by  
15 weight, and most preferably 1.0 to 5.0% by weight, calculated on the basis of the weight of the (co)polymer. Mixtures of the peroxy alkenylcarbonates according to the invention may also be employed. In addition, in certain situations it may be advantageous to use an auxiliary free radical generator which has a decomposition temperature  
20 lower than that of the peroxy alkenylcarbonate.

The (co)polymers modified in accordance with the present invention are useful for their standard applications although particular useful properties can be improved by the process of the present invention.  
25 In particular, due to the increased adhesion provided by the modification process, these modified (co)polymers are well suited for the fabrication of shaped objects. Further, these (co)polymers can be used in blends with other modified (co)polymers or with unmodified (co)polymers. For example, modified ethylene/propylene rubbers may be  
30 blended with unmodified nylon to significantly improve the impact strength of the nylon composition.

The modification process itself, is generally carried out at temperatures in the range of 50°C to 250°C., and preferably from 100°C

to 200°C, care being taken that the duration of the modification reaction under the given conditions is at least several half-life periods of the peroxy alkenylcarbonate.

5 As mentioned above, the (co)polymer may also contain the usual polymer additives. As examples of such additives may be mentioned: stabilizers such as inhibitors of oxidative, thermal or ultraviolet degradation, lubricants, extender oils, pH controlling substances such as calcium carbonate, release agents, colorants, reinforcing or non-reinforcing fillers such as silica, clay, chalk, carbon black and fibrous materials, nucleating agents, plasticizers, accelerators, and cross-linking agents such as peroxides and sulfur. These additives may be employed in the usual amounts.

15 The invention is further described in the following examples.

#### Example 1

##### Preparation of t-Butylperoxy Allyl Carbonate

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To a stirred mixture of 38.0 g. of water, 0.60 moles of t-butyl hydroperoxide (70%w/w) and 0.50 moles of allylchloroformate (98% w/w) were added over a period of 55 minutes. Then, 0.62 moles of an aqueous potassium hydroxide solution (45% w/w) was added with stirring at a temperature of 5-10°C and stirring was continued for an additional 45 minutes at 5-10°C. Thereafter, 60 g. of water was added to the reaction mixture at 10°C and the organic layer was separated and subsequently washed with 40 g. of an aqueous solution of NaOH (12.5% w/w) over a period of 5 minutes at 10°C; a mixture of 50 g. of water, 8 g. of NaAc/HAc buffer and 10 g. of Na<sub>2</sub>SO<sub>3</sub> solution over 15 minutes at 10°C; and a mixture of 54 g. of an aqueous solution of NaCl (25% w/w) and 6 g. of an aqueous solution of NaHCO<sub>3</sub> (6% w/w) over 15 minutes at 10°C. After drying the organic layer with a mixture of sodium sulfate and magnesium sulfate, 70.3 g. of a colorless liquid

was obtained having a peroxide content of 97.5% corresponding to a yield of 78.7%. The structure of the product was confirmed by NMR and IR spectroscopic analysis.

## 5     Example 2

### Preparation of 2,5-bis(peroxyallylcarbonate) 2,5-Dimethyl Hexane

10     To a stirred mixture of 115 ml of diethyl ether, 0.57 mol pyridine and 0.226 mole of 2,5-dimethyl-2,5-dihydroperoxyhexane (98% w/w) was added 0.534 mole of allylchloroformate (98% w/w) over a period of 55 minutes at 5-10°C. Stirring was continued for another period of 315 minutes at 5-10°C. Thereafter 145 g of water was added to the reaction mixture at 10°C. The organic layer was separated and subsequently washed with 15     84 g of HCl-1N, 5 minutes 5-10°C; 140 g of water, 5 minutes 5-10°C; four times with 50 g of an aqueous solution of KOH (2.5% w/w), 5 minutes 10°C; and 75 g of an aqueous solution of NaCl (2.5% w/w), 5 minutes 10°C.

20     After drying the organic layer with  $\text{MgSO}_4 \cdot 2\text{H}_2\text{O}$ , the solvent was removed under reduced pressure 0.8 mbar at 10°C. A viscous liquid was obtained, peroxide content 90.0% corresponding to a yield of 69%.

25     The structure of the product was confirmed by NMR and IR spectroscopic analysis.

## Example 3

### Preparation of t-Butylperoxy Isopropenylcarbonate

30     To a stirred mixture of 237 g. of n-pentane, 0.45 mole of pyridine and 0.40 mole of t-butylhydroperoxide (68% w/w in pentane) was added 0.396 mole of isopropenyl chloroformate (99% w/w) over a period of 35 minutes at 0°C. Stirring was continued for an additional period of 70 minutes at 0-5°C. Thereafter, 100 g. of water was added to the

reaction mixture at 0-5°C. The organic layer was then separated and subsequently washed with 100 g. of water over a period of 5 minutes at 0-5°C, 80 g. of 1 Normal HCl over a period of 5 minutes at 0-5°C twice, 85 g. of an aqueous solution of NaHCO<sub>3</sub> (2% w/w) over 5 minutes  
5 at 0-5°C twice, and 150 g. of an aqueous solution of NaCl (25% w/w) over 5 minutes at 0-5°C. After drying the organic layer with a mixture of Na<sub>2</sub>SO<sub>4</sub> and MgSO<sub>4</sub>, the solvent was removed under a reduced pressure of 0.8 mbar at 10°C. 61 g. of a colorless liquid was obtained having a peroxide content of 89.7% corresponding to a yield of 79.3%. The  
10 structure of the product was confirmed by NMR and IR spectroscopic analysis.

#### Example 4

#### 15 Modification of Low Density Polyethylene

On a two-roll mill (225x110 mm.) at 110°C polyethylene in powder form (Lacqtene 1070 MN 040) is mixed with peroxy alkenylcarbonate. A Haake Rheocord System 40 fitted with an electrically heated roller mixer  
20 chamber type Rheomix 600 is employed to carry out the modification reaction. The mill is operated at 30 rpm (friction 3:2), a ram pressure of 60 kPa, and the reaction is carried out over a period of one hour. A modified low density polyethylene polymer is obtained. The amount of peroxy alkenylcarbonate, polymer, the reaction  
25 temperatures, the torque analysis and the physical properties of the modified polyethylene are listed in Table 1. The Fourier Transform Infrared (FTIR) spectrum for this modified polyethylene confirms the presence of cyclic carbonate functionalities in the polymers.

30 A sample of each modified polymer was compressed into a plate 1 mm thick over a period of 15 minutes, and at a temperature of 160°C. Subsequently, the peel strength of a bi-component lacquer and the lap shear strength using an epoxy resin were measured.



The 180° peel strength was determined according to ASTM-D 429-81 using a Zwick® tensile tester 1474 at 25 mm/min. Besides indicating the nature of the failure, the peel strength is reported by this method as (average peel force)/(diameter of test pieces).

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The lap shear strength was measured using an epoxy resin of the following composition: 10 g. of bisphenol A/F epoxy resins (Epikote® DX 235, ex. Shell), 6 g. of polyaminoamide (Epilink® 177, ex. Akzo Chemicals) and 0.08 g. of silan® A 174 (ex. Union Carbide). A thin film of resin was applied to the adhesion surface area (20x15 mm) of a modified polymer plate (40x20x1 mm). Another modified polymer plate was placed on the adhesion surface area and the two parts were firmly clamped together to avoid occlusion of air. This composition was kept in a stove for 72 hours at 30°C.

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The lap shear strength was determined on a Zwick® tensile tester 1474 by measuring the force (kg/cm<sup>2</sup>) needed to separate the plates from each other at a speed of 25 mm/min. If the adhesion fails by shifting apart of the two pieces of polymer, the measured force is a measure for adhesion of the epoxy resin. If the polymer breaks before the adhesion fails the force at which the adhesion will fail is not measurable but it will be at least higher than the force required for polymer breakage.

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Table 1

	Reference Standard	t-butylperoxy allyl carbonate	t-pentenylperoxy allyl carbonate
Amount of Lacqtene 1070 MN040(g)	46.00	44.41	44.20
Amount of Modifying additive(g)	--	1.59	1.80
<u>Torque analysis</u>			
M <sub>min</sub> (Nm)	12.5	13.2	13.2
time till M <sub>min</sub> (min)	60	7.6	6.0
ΔM (Nm)	--	27.9	0.8
time till M <sub>max</sub> (min)	--	50	10
M <sub>60</sub> : torque after 60 min (Nm)	12.5	40	12.5
<u>Temperature analysis</u>			
temp. at M <sub>min</sub> (°C)	120	119	118
temp. at M <sub>max</sub> (°C)	120	148	121
max. temp. reached = T <sub>max</sub> (°C)	120	149	122
time till T <sub>max</sub> (min)	19.4	60.5	142
temp. end reaction (°C)	120	148	122
<u>Physical Properties</u>			
Adhesion-PUR lacquer (10 <sup>-2</sup> xN/mm)	8	10	8
Maximum adhesion value (10x <sup>-2</sup> N/mm)	9.8	13.5	10.3
Lap Shear Strength (MPax10 <sup>-2</sup> )	23	28	33
Maximum lap shear value (MPax10 <sup>-2</sup> )	23	38	37

Example 5Modification of Polypropylene

5 Polypropylene (Hostalen PPU 0810 P) is mixed with peroxy alkenylcarbonate and a coagent. A Haake Rheocord System 40 fitted with an electrically heated roller mixer chamber type Rheomix 600 is employed to carry out the modification reaction. The mill is operated at 30 rpm (friction 3:2) and a ram pressure of 60 kPa, and the  
10 reaction is carried out over a period of fifteen minutes. A modified polypropylene polymer is obtained. The amount of peroxy alkenylcarbonate, polymer, coagent, the reaction temperatures, the torque analysis and the physical properties of the modified polypropylene are listed in Table 2. The FTIR spectrum for  
15 polypropylene modified with t-butyl peroxy allyl carbonate confirms the presence of cyclic carbonate functionalities in the modified polymer. The FTIR spectrum for polypropylene modified with t-butyl peroxy isopropenyl carbonate confirms the presence of ketone functionalities in the modified polymer.

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Table 2

	Reference Standard	t-butylperoxy allyl carbonate	t-butylperoxy isopropenylcarbonate	t-pentenylperoxy allyl carbonate
Amount of Hostalen PPU0810(g)	44.88	43.36	43.24	43.16
Amount of Modifying additive(g)	--	1.56	1.68	1.76
Amount of Coagent (g.)	1.12	1.08	1.08	1.08
<u>Torque analysis</u>				
M <sub>min</sub> (Nm)	0.187	0.331	0.165	0.135
time till M <sub>min</sub> (min)	15	1.5	15	12.3
ΔM (Nm)	0	0.135	0	0
time till M <sub>max</sub> (min)	--	2.5	--	0
M <sub>15</sub> : torque after 60 min (Nm)	0.187	0.227	0.165	0.175
<u>Temperature analysis</u>				
temp. at M <sub>min</sub> (°C)	178	160	177	178
temp. at M <sub>max</sub> (°C)	--	165	--	--
max. temp. reached = T <sub>max</sub> (°C)	178	178	179	178
time till T <sub>max</sub> (min)	12.0	12.0	5.0	10.5
temp. end reaction (°C)	178	178	177	175
<u>Physical Properties</u>				
Adhesion-PUR lacquer (10 <sup>-2</sup> xN/mm)	8	15	9	10
Maximum adhesion value (10 <sup>-2</sup> xN/mm)	9.1	20	11	13
Lap Shear Strength (MPax10 <sup>-2</sup> )	23	> 95.6	> 101.2	> 79.8
Maximum lap shear value (MPax10 <sup>-2</sup> )	23	101.7	116.5	125.0

Example 6Modification of Polyethylene With a Diallyl Peroxy Carbonate

5 Polyethylene in powder form (Lacqtene 1070 MN 040) is mixed with  
diallyl peroxy carbonate. A Haake Rheocord System 40 fitted with an  
electrically heated roller mixer chamber type Rheomix 600 is employed  
to carry out the modification reaction. The mill is operated at 30  
10 rpm (friction 3:2), a ram pressure of 60 kPa, and the reaction is  
carried out over a period of one hour. A modified low density  
polyethylene polymer is obtained.

Example 7

15 Modification of Polyphenylene Ether with t-Butyl Peroxy Allyl  
Carbonate

Polyphenylene ether (PPE), Noryl 800 in powder form (ex. General  
Electric Plastics) is modified with 20 meq./100g. PPE of t-butyl  
20 peroxy allyl carbonate in a roto vapor apparatus at 150°C over a  
period of 60 minutes.

The Fourier Transform Infrared (FTIR) Spectrum for the modified PPE  
demonstrates that the polymer contains cyclic carbonate  
25 functionalities. A sample of unmodified PPE shows no cyclic carbonate  
functionalities when subjected to FTIR analysis.

Example 8

30 Blends of Modified PPE and Polyamid-6

The modified PPE from example 7 is blended with polyamid-6 (PA-6)  
(Akulon M138 ex. Akzo), in a weight ratio of modified PPE to PA-6 of  
55/45. The blending is carried out in a Haake Rheomix 600 with roller

sensors at 80 rpm, a set temperature of 260°C over a 10 minute period. The data from a torque analysis are presented in Table 3 for a standard blend of unmodified PPE with PA-6 and a blend of the modified PPE with PA-6 made in accordance with this example.

5

The mechanical properties of the blends were determined on 200x120x1 mm compression molded sheets pressed at 260°C for 4 minutes without pressure, 1 minutes at 50 KN and 1 minute at 150 KN. The resultant properties were measured on a Zwick 1475 tensile tester according to

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DIN 53504 and are also given in Table 3.

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Table 3  
Standard PPE/PA-6      Modified PPE/PA-6

	Akulon M138 (PA-6)	45	45
5	Modified PPE	0	55
	PPE	55	0
	<u>Torque analyses:</u>		
	Mmin	Nm	7.86
10	time till Mmin	min	10.00
	delta M	Nm	0.00
	time till Mmax	min	-
	M10	Nm	7.86
			14.32
	<u>Temperature analyses:</u>		
15	temp. at Mmin	°C	274
	temp. at Mmax	°C	274
	max. temp. reaches=Tmax	°C	275
	time till Tmax	min	7.00
	temp. end reaction	°C	274
20			284
	<u>Mechanical Properties:</u>		
	Tensile Strength	MPa	35.89
	Elongation at Fmax	%	5.54
	Rupture Strength	MPa	35.90
25	Elongation at Rupture	%	5.54
	Youngs Modulus	MPa	1261.10
			1946.19

30 As can be seen from the data presented in table 3, the modified PPE/PA-6 blends exhibit a higher torque, higher tensile strength, better elongation at rupture and a greater Young's modulus than the same blend using unmodified PPE.

Example 9Modification of High Density Powdered Polyethylene with t-Butyl Peroxy Allyl Carbonate

5 High density polyethylene (HDPE). (Marlex 56020 in powder form, ex. Phillips Pet. Chem.), is modified with 20 meq./100 g. HDPE of t-butyl peroxy allyl carbonate in a roto vapor apparatus at 150°C over a period of 60 minutes. The FTIR spectrum for the modified HDPE  
10 demonstrates that the modified HDPE contains cyclic carbonates. The FTIR spectrum for unmodified HDPE shows no absorption band at the same frequency. This modified HDPE is useful in polymer blends or as a filler material for other polymers.

15 The foregoing examples show that polypropylene, polyphenylene ether and both high and low density polyethylene, when modified by the process of the present invention, exhibit improved physical properties. The ability to improve these physical properties by  
20 employing the simple and inexpensive process of the present invention provides a wide range of possibilities for improving the suitability of polymeric materials for their present applications as well as adapting these polymeric materials to new and different applications.

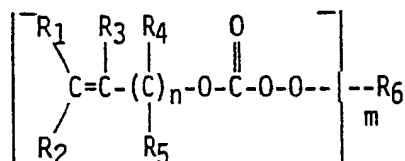
25 The foregoing description and examples of the invention were presented for the purpose of illustration and description only and are not to be construed as limiting the invention in any way. Accordingly, the scope of the invention is to be defined by the claims appended hereto.

30

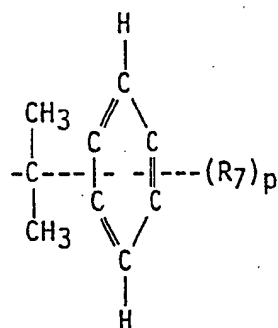


What is claimed is:

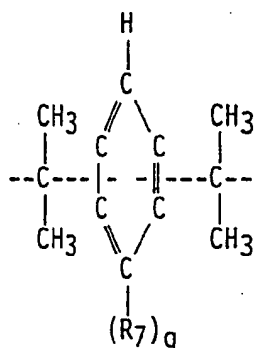
1. A process for the preparation of a modified (co)polymer by using an organic peroxide, said process comprising the step of contacting a peroxide of the formula:



wherein  $R_1$ ,  $R_2$ ,  $R_4$ , and  $R_5$  may be the same or different and represent H or  $C_{1-4}$  alkyl groups;  $n = 0$  or 1;  $m = 1, 2$ , or 3;  $R_3 = H$ ,  $C_{1-4}$  alkyl or an electron withdrawing group; and when  $m=1$ ,  $R_6 =$  a tertiary alkyl group optionally substituted with a hydroxyl group and containing 4-18 carbon atoms, p-menth-8-yl or a group of the general formula:



wherein  $p = 0, 1$  or 2 and  $R_7$  is an isopropenyl group, a 2-hydroxyisopropyl group, or an isopropyl group;  
when  $m = 2$ ,  $R_6 =$  an alkylene group having 8-12 carbon atoms and a tertiary structure at both ends thereof, an alkynylene group having 8-12 carbon atoms and a tertiary structure at both ends thereof, or a group of the general formula:



10 wherein  $q = 0$  or  $1$  and  $R_7$  has the above-indicated meaning; and when  $m = 3$ ,  $R_6 = 1,2,4$ -triisopropylbenzene- $\alpha, \alpha', \alpha''$ -triyl or 1,3,5-triisopropylbenzene- $\alpha, \alpha', \alpha''$ -triyl; with a (co)polymer whereby the peroxide is decomposed and the (co)polymer is modified.

- 15 2. A process according to claim 1 characterized in that  $R_1$ ,  $R_2$  and  $R_3$  are selected from the group consisting of hydrogen and methyl.
3. A process according to claim 1 or 2, characterized in that  $m=2$ .
- 20 4. A process according to claim 1, characterized in that the peroxide is selected from the group consisting of t-butylperoxy allylcarbonate, t-pentenylperoxy allylcarbonate, t-butylperoxy isopropenylcarbonate, t-pentenylperoxy allylcarbonate, 2,5,-bis(peroxyallylcarbonate) 2,5-dimethyl hexane,
- 25 t-pentenylperoxy 4-propyl-4-heptene carbonate, t-octylperoxy 3-butyl-3-hexene carbonate and t-nonylperoxy 2-methyl-2-pentene carbonate.
- 30 5. A process according to any one of claims 1-4, characterized in that the amount of peroxide that is contacted with the (co)polymer is 0.01 to 15% by weight of the (co)polymer, the reaction temperature is from 50-250°C, and the duration of the modification step is at least five half-life periods of the peroxide.

6. A process according to claim 5, characterized in that the added amount of peroxide is 0.1 to 10% by weight of the (co)polymer and the reaction temperature is from 100-200°C.
- 5 : 7. A process according to any one of claims 1-6, further characterized in that the peroxide is contacted with the (co)polymer in the presence of a coagent.
- 10 8. A process according to claim 7, wherein the coagent is selected from the group consisting of di- and triallyl compounds, di- and tri-(meth)acrylate compounds, bismaleimide compounds, divinyl compounds, polyalkenylbenzenes and their polymers, vinyl toluene, vinyl pyridine, parachinone dioxime, polybutadiene and their derivatives.
- 15 9. A process according to one of claims 1-8, characterized in that the (co)polymer is selected from the group consisting of polyethylene, polypropylene, polyphenylene ether, ethylene/propylene copolymer, ethylene/vinylacetate copolymer, 20 ethylene/propylene/dienemonomer terpolymer, 2,6-dimethylpolyphenyleneoxide, and mixtures thereof.
- 25 10. A process according to any one of claims 1-9, characterized in that the (co)polymer is degraded during the modification step.
11. A process according to any one of claims 1-9, characterized in that the (co)polymer is cross-linked during the modification step.
- 30 12. A shaped object manufactured using a (co)polymer prepared by the process according to any one of claims 1-11.
13. A shaped object manufactured using two or more (co)polymers, of which at least one is a (co)polymer prepared by the process according to any one of claims 1-11.

# INTERNATIONAL SEARCH REPORT

International Application No PCT/EP 90/01045

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>8</sup> According to International Patent Classification (IPC) or to both National Classification and IPC IPC <sup>5</sup> : C 08 F 8/50																	
<b>II. FIELDS SEARCHED</b> <div style="text-align: right; font-size: small;">Minimum Documentation Searched <sup>7</sup></div> <table style="width: 100%; border: none;"> <tr> <td style="width: 30%; border-bottom: 1px solid black;">Classification System</td> <td style="border-bottom: 1px solid black;">Classification Symbols</td> </tr> <tr> <td style="padding: 5px;">IPC<sup>5</sup></td> <td style="padding: 5px;">C 08 F, C 08 K</td> </tr> </table> <div style="text-align: center; font-size: x-small; margin-top: 5px;">           Documentation Searched other than Minimum Documentation            to the Extent that such Documents are Included in the Fields Searched <sup>6</sup> </div>			Classification System	Classification Symbols	IPC <sup>5</sup>	C 08 F, C 08 K											
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<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b> <table border="1" style="width: 100%; border-collapse: collapse; font-size: x-small;"> <thead> <tr> <th style="width: 10%;">Category <sup>9</sup></th> <th style="width: 70%;">Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup></th> <th style="width: 20%;">Relevant to Claim No. <sup>13</sup></th> </tr> </thead> <tbody> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">GB, A, 2081282 (NIPPON OIL AND FATS) 17 February 1982 see claim 1 (cited in the application)  --</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">EP, A, 0208353 (AKZO) 14 January 1987 see claims 1-5  --</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">EP, A, 0273990 (AKZO) 13 July 1988 see claims 1-6 (cited in the application)  --</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> <tr> <td style="text-align: center; vertical-align: top;">A</td> <td style="vertical-align: top;">EP, A, 0273274 (LUPEROX) 6 July 1988 see claims 1-11; page 5 -----</td> <td style="text-align: center; vertical-align: top;">1</td> </tr> </tbody> </table> <div style="font-size: x-small; margin-top: 10px;"> <div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> <p><sup>9</sup> Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 48%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents; such combination being obvious to a person skilled in the art</p> <p>"Z" document member of the same patent family</p> </div> </div> </div>			Category <sup>9</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>	A	GB, A, 2081282 (NIPPON OIL AND FATS) 17 February 1982 see claim 1 (cited in the application)  --	1	A	EP, A, 0208353 (AKZO) 14 January 1987 see claims 1-5  --	1	A	EP, A, 0273990 (AKZO) 13 July 1988 see claims 1-6 (cited in the application)  --	1	A	EP, A, 0273274 (LUPEROX) 6 July 1988 see claims 1-11; page 5 -----	1
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<b>IV. CERTIFICATION</b> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-bottom: 1px solid black;">Date of the Actual Completion of the International Search</td> <td style="width: 50%; border-bottom: 1px solid black;">Date of Mailing of this International Search Report</td> </tr> <tr> <td style="padding: 5px;">15th October 1990</td> <td style="padding: 5px;">09. 11. 90</td> </tr> <tr> <td style="width: 50%; border-bottom: 1px solid black;">International Searching Authority</td> <td style="width: 50%; border-bottom: 1px solid black;">Signature of Authorized Officer</td> </tr> <tr> <td style="padding: 5px; text-align: center;">EUROPEAN PATENT OFFICE</td> <td style="padding: 5px; text-align: center;">             H. Halesieros         </td> </tr> </table>			Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	15th October 1990	09. 11. 90	International Searching Authority	Signature of Authorized Officer	EUROPEAN PATENT OFFICE	 H. Halesieros							
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# ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

EP 9001045

SA 38451

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2081282	17-02-82	JP-A, B, C57023615	06-02-82
		FR-A, B 2486951	22-01-82
		NL-A- 8103414	16-02-82
		US-A- 4366290	28-12-82
EP-A- 0208353	14-01-87	CA-A- 1271585	10-07-90
		JP-A- 62001733	07-01-87
		US-A- 4833209	23-05-89
		US-A- 4774293	27-09-88
EP-A- 0273990	13-07-88	None	
EP-A- 0273274	06-07-88	DE-A- 3642266	23-04-87

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